

**QUALITY CONTROL MANUAL  
FOR FABRICATION & INSTALLATION OF  
PVC AND UltraTech<sup>®</sup> GEOMEMBRANES**

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## **Preface**

EPI is committed to not only satisfying all appropriate industry and customer specifications, but also continuing to establish new standards of product and service excellence.

Our management and employees regularly assess all aspects of our design, fabrication, shipping, installation and testing procedures to assure we are meeting this commitment.

We are also committed to continuing to be an industry leader in the use of new technology and independent research and development.



**The Liner Company**

***"ENHANCING OUR ENVIRONMENT BY PRESERVING  
WATER RESOURCES FOR FUTURE GENERATIONS"***



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## **1. SCOPE**

This manual presents EPI's basic quality control system for the fabrication, packaging, installation and testing of its polyvinyl chloride (PVC) and UltraTech® liners. As appropriate, the policies and procedures are also applied for projects involving other geomembrane material.

### **1.01 QUALITY STANDARDS**

The products and services of EPI meet or exceed the PVC Geomembrane Institute's PGI-1104 specifications requirements for specified geomembrane liners. EPI's specifications for PVC and UltraTech are included in the appendix.

The testing procedures are consistent with or exceed the requirements of the American Society for Testing and Materials (ASTM) as appropriate. Laboratory testing equipment is certified and traceable to the standards of the National Institute of Standards and Traceability (NIST).

EPI shall also adhere to the standards as called for in site specific contract plans, specifications and CQC \ CQA documents, consistent with the PVC Geomembrane Institute's PGI-1104 specifications.

### **1.02 ADHERENCE TO STANDARDS**

The procedures herein will be adhered to at all times. The material here supersedes all previous procedures relating to quality control.

The supply and installation of these materials will be in strict accordance with the Engineer's specifications and engineering drawings. Deviation from the standards and procedures described in this manual will only be as required for unique project specifications, according to the terms and conditions of the contract.

Conformance to the established policies and procedures described herein will be monitored by internal audits on a random basis.

### **1.03 WARRANTIES**

EPI will provide the OWNER, as part of the project documents, a specific written warranty. This document will warrant the quality of the PVC geomembrane materials, factory seams and workmanship.

EPI will certify in writing that the installed material meets the requirements of the project and the specification and that, under normal soil covered conditions, the sheet material can be warranted by the material manufacturer for up to twenty years, and that the installation workmanship is warranted for one year.



#### 1.04 DISPOSITION OF SAMPLES AND TESTED MATERIALS

Every sample and test taken, in accordance with the specifications of the installation and the procedures described herein, will consist of two parts:

- a) EPI will deliver one part to the OWNER or his representative along with the project documentations, upon the OWNER's written request.
- b) EPI will retain and will test and/or archive the other part at its own facility along with EPI's copy of the documentation for the installation.

After testing, all samples, specimens and test reports are the property of EPI.

Additional samples and test material may be taken by EPI for testing at its own laboratory, for its own use and information.

Additional sample and test material may be made available to an independent testing laboratory or the OWNER's representative at the OWNER's expense.

## 2. IN - FACTORY QUALITY CONTROL

### 2.01 RAW MATERIALS INSPECTION

- a) EPI requires each manufacturer to furnish written certification that all material meets or exceeds EPI's specifications and the PVC Geomembrane Institute's specifications as well as PGI-1104 as appropriate.
- b) Prior to factory seaming, all roll goods will be unwound and visually inspected for contaminants, defects, undispersed raw materials and edge uniformity.
- c) All defects or impurities will be removed from the roll prior to being fabricated into panels, or the roll will be rejected.
- d) Thickness measurements will be made at the beginning and end of each roll of material.
- e) Material will be rejected for poor "layflat" edges or "racetracking" caused by inconsistent sheet thickness.



**2.02 RAW MATERIALS TESTING**

Tests will be conducted by EPI on samples from each 10,000 pound lot geomembrane roll goods material received to verify compliance with the PVC Geomembrane Institute's PGI-1104 specifications in the following areas:

<u>PROPERTY</u>	<u>TEST METHOD</u>
Surface Uniformity	Visual
Thickness (gauge, nominal)	Micrometer-ASTM D1593
Minimum Tensile Properties (minimum each direction)	
1. Breaking Factor (lbs/in. width)	ASTM D882
2. Elongation at Break (percent)	ASTM D882
3. Modulus (force) at 100% Elongation (lbs./in. width)	ASTM D882

**2.03 FABRICATION AND IN - FACTORY SEAMING**

The calendered sheets will be factory seamed into maximum sized panels, and custom designed for the specific project so as to minimize field seams. The following practices will be an integral part of the fabrication process:

- a) The factory seam process will typically be accomplished by the use of chemical fusion welding. The weld will have a minimum width of one inch.
- b) All factory seams will extend to the end of the sheet. No loose edges will be allowed.
- c) Each individual strip of material is numbered to correspond with shop fabrication drawings to assure accurate size.
- d) Each individual strip is marked at its centerline to assure "square" finished panels.
- e) A reinforcing patch is applied to the end of seams in "stepped" panels.
- f) Each panel fabricated is logged by serial number, size, date fabricated, material lot number, roll number and fabrication crew.

**2.04 FACTORY SEAM REQUIREMENTS**

Factory seams for PVC membrane will meet or exceed the following requirements as specified by PVC Geomembrane Institute PGI-1104 :

<u>PROPERTY</u>	<u>TEST METHOD</u>	<u>VALUE</u>
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Bonded Seam Strength (factory seam, breaking, lbs/in width)	ASTM D882 (as modified by PGI)	80% of specified tensile strength
Peel Adhesion (lbs/in width min.)	ASTM D413	10 Mil - 10 lbs/in width or FTB* 20 Mil - 12.5 lbs/in width or FTB* 30 Mil - 15 lbs/in width or FTB* 40 Mil - 15 lbs/in width or FTB* 50 Mil - 15 lbs/in width or FTB* 60 Mil - 15 lbs/in width or FTB* <i>*FTB = Film Tearing Bond</i>

Factory seams for UltraTech membrane will meet or exceed the following requirements:

<u>PROPERTY</u>	<u>TEST METHOD</u>	<u>VALUE</u>
Bonded Seam Strength (factory seam, breaking, lbs/in width)	ASTM D882 (as modified by PGI)	80% of specified tensile strength
Peel Adhesion (lbs/in width min.)	ASTM D413	10 lbs/in width or FTB* <i>*FTB = Film Tearing Bond</i>

**2.05 IN - FACTORY SEAM TESTING**

- a) **NON - DESTRUCTIVE TESTING**  
All completed factory seams are 100% visually inspected by two people. Every third seam is visually inspected on both sides. Factory seams will be visually inspected for full seam continuity over their full length during the folding operation by tensioning the seam perpendicular to the seam length. Any areas that do not meet the specified requirements shall be removed and repaired per section 2.05 (c).
  
- b) **DESTRUCTIVE TESTING**  
Destructive tests will be performed to verify that the seam strength requirements of the specifications are met. Random samples shall be taken at a minimum of every 3,000 lineal feet of factory seam or once per factory panel fabricated, whichever is more frequent, and the following quality assurance tests will be performed on each sample:
  - thickness
  - bonded seam strength (shear strength)
  - peel adhesion
 The sample shall be cut into ten one - inch wide specimens. For EPI's standard statistical program, six peel and four bonded seam specimens are



removed. Four specimens shall be tested for bonded seam strength (bss) and four for peel adhesion. The additional two peel specimens are used for the Wolschon test specified in 2.07 (see figure 1 in appendix). To be acceptable, the average of four test specimens for peel and the average of four test specimens for bonded seam strength must meet the minimum peak load requirements of factory seams as follows:

#### **Bonded Seam Strength**

One-inch strips cut with the weld centrally located are tested by stressing the weld in a "shear" configuration. That is, the top sheet is stressed in relation to the bottom sheet in a direction away from the weld. A pass result occurs when the specimen averages meet the minimum peak load requirements stated in the contract (usually 80% of specified sheet strength). A failure occurs when the weld separates or the material breaks at a peak load less than the minimum requirements. The test result to be reported will be the average of the peak loads recorded for each of the four specimens.

#### **Peel Adhesion**

One-inch strips cut with the weld centrally located are tested by stressing the top sheet in relation to the overlapped edge of the lower sheet in an effort to peel the weld away. Each specimen will be peeled two inches along the seam length. A pass result occurs when the specimen meets the minimum peak load requirements stated in the contract. A failure occurs when the weld peels at a peak load less than the specification without film tearing bond. The test result to be reported is the average of the peak loads recorded for each of the four specimens.

Each test will be identified by EPI serial number and the manufacturer's roll number. These tests shall be performed in EPI's laboratory.

Prior to installation of the geomembrane at the site, EPI will provide to the ENGINEER, manufacturer material certifications and/or a copy of quality control test results for all panels to be used, verifying conformance with this specification and the requirements as represented in PVC Geomembrane Institute PGI-1104 specification. The location of any defects and repairs and all necessary retesting results will also be documented in the report.

#### c) REPAIRS

When a seam sample is removed from the panel being fabricated the resulting hole will be repaired with a patch with a minimum of a one inch bonded area around the patch, and the patch will be rounded on all corners.

## **2.06 STATISTICAL PROCESS CONTROL (SPC)**

EPI follows a consistent Statistical Process Control (SPC) Program of inspection and testing throughout the factory fabrication process. The statistics developed through this



program give EPI the ability to interpret information and predict changes needed in the fabrication process before unwanted results occur.

EPI maintains Average and Range (X - BAR - R) process control charts on all results obtained from seam shear and peel tests conducted in EPI's laboratory. The results shown on these charts are reviewed regularly with EPI management personnel, each fabricator, and with the Quality Improvement Team.

EPI maintains histograms of the results of tests performed on samples taken from each lot of geomembrane material received. These tests include visual inspection, thickness, tensile strength, elongation and modulus of elasticity.

EPI's Quality Control Program requires written confirmation of the following, any time a test result is above or below statistical control limits:

- Cause Identification
- Effect Identification
- Corrective Action Taken

EPI's tensile test equipment is recalibrated annually by an independent testing laboratory. The test equipment calibration is verified weekly by EPI.

## **2.07 Wolschon Testing**

A sample is removed from the actual factory fabrication process and, after five minutes, two specimens are tested for peel strength per ASTM D882. EPI refers to this procedure as the Wolschon Test, after it's developer Mark Wolschon, EPI's Quality Control Manager. The Wolschon Test data is then compared with previous data in correlation charting with standard ASTM D882 tests. A direct correlation exists between the peel strength of the Wolschon Test specimens compared to specimens from the same sample tested after forty hours. EPI has established lower limits for Wolschon Test results which will ensure minimum peel strength results after 40 hours per Section 2.04. If Wolschon Test lower limits are not met, corrective action procedures are in place which will rectify problems before production continues. All test results are analyzed in EPI's statistical process control program.

## **3. SHIPPING AND HANDLING**

### **3.01 PREPARATION FOR SHIPMENT**

- a) Factory fabricated geomembrane panels are normally packaged accordion folded on a sturdy wooden pallet designed for fork lift truck access. Smaller panels (i.e. less than 500 lbs.) are rolled on a fiber core, and placed on a pallet.
- b) Each panel will be prominently and indelibly marked with the panel size and serial number for proper deployment location according to shop drawings.



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- c) Pallets have a protective layer (i.e.: cardboard or excess liner) on the surface of the pallet and between the liner and the banding to prevent damage to the liner.
- d) All panels will be packaged with a protective, black stretch wrap cover to protect the panel from weather and ultraviolet light.

### 3.02 TRANSPORTING PANELS TO THE JOB SITE

The geomembrane panels will be packaged and shipped by appropriate means so that no damage is caused. Transportation is the responsibility of EPI, unless otherwise specified.

Materials will be shipped in either a closed trailer or on a flat bed trailer with adequate tarps, and delivered to the site only after the required submittals have been approved and received by EPI from the ENGINEER.

EPI will be responsible for repairing or replacing any material damaged during shipment at no cost to the OWNER.

### 3.03 UNLOADING

Prior to unloading the geomembrane from the trailer, any obvious damage to the material must be documented on the freight bill by the OWNER.

Any damage during off - loading will be documented by the contractor unloading the material.

Any obvious damage to the material should also be reported to EPI within 24 hours of receiving.

If a forklift is not available, slings should be used to lift pallets off the trailer with a cradle style lift in a way that will not damage the geomembrane material.

### 3.04 STORAGE

EPI will be allocated sufficient space by the OWNER to store the geomembrane upon its arrival. Proper on - site security is the responsibility of the OWNER.

The panels must remain stored in their original unopened containers in a dry area protected from damage.

Pallets will be stored on a prepared level surface as close to the work area as possible. The pallets should not be stacked.

The geomembrane will be stored so as to be protected from puncture, dirt, grease, water, moisture, mud, mechanical abrasions, excessive heat, extreme cold or other damage.



If the geomembrane will be installed at ambient temperatures below 60°F, provisions must be made to store the geomembrane in a heated area to maintain the material sheet temperature above 60°F. This storage area should be as close to the installation site as possible.

### **3.05 ON - SITE HANDLING**

On - site handling of the geomembrane is the responsibility of EPI. Appropriate handling equipment will be used when loading or moving the PVC panels from one place to another.

### **3.06 PALLET PLACEMENT**

Pallet placement shall be performed by EPI installation personnel upon their arrival at the job site. Placement of each pallet will be marked with survey flags, according to the shop drawings, by the EPI installation crew.

Pallet placement should be done only after the project area has been measured to assure conformance with the design and the subgrade has been approved by the installation foreman.

### **3.07 DAMAGED MATERIAL**

Any damage to the geomembrane caused by EPI will be carefully documented. If the damaged geomembrane cannot be satisfactorily repaired to comply with the specifications, it will be removed from the work area by EPI and replaced with acceptable geomembrane material at EPI's expense.

## **4. FIELD INSTALLATION PROCEDURES**

### **4.01 FIELD MEETINGS**

- a) **ON SITE PRE - INSTALLATION MEETING**  
EPI's field installation foreman will be available to meet with the OWNER, ENGINEER and CONTRACTOR prior to commencement of liner installation. The purpose of this meeting is to:
  - Review EPI's responsibilities.
  - Review construction schedule.
  - Assess any unusual or special requirements
  
- b) **DAILY MEETING**

A daily meeting will be held at the work area just prior to commencement of the work day. At minimum, the meeting should be attended by the EPI field installation foreman, the INSPECTOR and CONTRACTOR. The purpose of the meeting is to:



- Review the work activity and location for the day.
- Discuss EPI's personnel assignments for the day.
- Review the previous day's activity.
- Review the work schedule.
- Discuss possible problem areas and situations.
- Discuss all safety policies and/or special concerns

#### 4.02 AREA SUBGRADE PREPARATION

##### a) SUBGRADE

Surfaces to be lined will be smooth and free of all rocks and stones greater than 1/2" diameter, sticks, sharp objects, or debris of any kind. The surface should provide a smooth, flat, firm, unyielding foundation for the membrane with no sudden, sharp or abrupt changes or break in grade.

No standing water, mud, snow and excessive moisture will be allowed. The liner will not be deployed in the presence of mud, snow or frozen subgrade conditions.

The maximum slope for PVC geomembrane should not exceed 3 horizontal to 1 vertical.

If the liner is to be installed at an elevation below the current or possible future ground water elevation, the OWNER will be responsible for providing an adequate underdrain system to prevent ground water pressure beneath the liner. Excessive ground water or gas pressure can force the liner upwards through the cover soil and any liquid contained in the impoundment.

Special care will be taken to maintain the prepared soil surfaces. The soil surface will be observed daily by EPI to evaluate the surface condition. Any damage to the surface caused by weather conditions or circumstances beyond the control of EPI will be repaired by the grading contractor.

##### b) SUBGRADE CERTIFICATION

EPI will certify in writing that the SURFACE on which the membrane is to be installed is acceptable before commencing work. This certification will not be given until all required soil testing has been completed and approved by the OWNER or ENGINEER. A copy of this certificate is included in Appendix A.

##### c) SUBGRADE REPAIR

Immediately prior to installation of the designated geomembrane, soil surfaces will be observed by the EPI installation Foreman and the OWNER or his representative. No geomembrane material will be placed on a subgrade that has become softened by water or overly dried until it has



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been properly reconditioned and/or recompacted. All subgrade repairs required will be performed by the grading contractor.

### d) VEGETATION CONTROL

If the OWNER or ENGINEER requires a soil sterilant, the herbicide will not be harmful to the liner and will be applied according to its manufacturer's recommendations. The soil sterilant must be applied at least 48 hours prior to liner installation.

### e) ANCHOR TRENCHING

The anchor trench will be excavated to the line, grade and width shown on the construction drawings, prior to liner placement. The OWNER or ENGINEER will verify that the anchor trench has been constructed according to construction drawings.

If the anchor trench is located in a subgrade susceptible to desiccation; no more than the amount of trench required for the geomembrane to be anchored in one day will be excavated to minimize desiccation of the anchor trench soils.

Slightly rounded corners will be provided in the trench where the geomembrane adjoins the trench so as to avoid sharp bends in the geomembrane. No loose soil or rocks will be allowed to underlie the geomembrane in the anchor trench. Leading edges of the anchor trench should be smooth and even.

## 4.03 LINER PLACEMENT

The EPI installation Foreman shall ensure the following:

- a) No equipment or tools will damage the geomembrane by handling, traffic or other means. Clamps and metal tools are padded or have rounded corners and are never tossed or thrown above the geomembrane. Knives and other sharp tools will be carried in protective sheaths.
- b) No personnel working on the geomembrane will smoke, wear damaging shoes or engage in other activities that could damage the geomembrane.
- c) The method used to unfold the panels will not cause damage to the geomembrane and will not damage the supporting soil or any underlying geotextile.
- d) The method used to place the panels will minimize wrinkles (especially differential wrinkles between adjacent panels). Minimum wrinkles will be allowed to ensure the liner is installed in a relaxed condition. Stretching of the Geomembrane will not be allowed.



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- e) Adequate ballast (e.g., cover soil or similar measures that will not damage the geomembrane) will be placed to prevent uplift by wind. In case of high winds, continuous loading is recommended along edges of panels to minimize risk of wind flow under the panels.
- f) Direct contact with the geomembrane by equipment will be minimized, i.e., the geomembrane in traffic areas is protected by geotextiles, extra geomembrane, or other suitable cover materials or cover soil.
- g) No vehicles, other than those approved by the installer, are allowed on the geomembrane. Small rubber tired equipment with a ground pressure not exceeding 5 psi, and a total weight not exceeding 750 lbs will normally be allowed i.e., air compressors, generators, etc. that would be required during installation and testing.
- h) Seaming adhesives, fusion chemicals, hydrocarbons or chemical cleaning agents are to be stored separately, away from geomembrane panels, and only spill resistant containers should be used while working on the geomembrane.

### 4.04 WEATHER CONDITIONS

Geomembrane deployment will proceed when ambient temperature and material sheet temperature are between 60°F and 105°F. Sheet temperature will be measured on the membrane surface by an infrared thermometer or surface contact thermometer.

If the soil beneath the geomembrane is frozen, the heat from hot air guns, hot wedge welders or any preheating equipment that may be used can thaw the frost allowing water to be condensed onto the unbonded region ahead of the seam being welded. This possibility may be eliminated by the use of suitable seaming boards or slip sheets made from excess geomembrane. For sheet temperatures below 40°F, shielding, preheating, different chemical compounds and/or a slower seaming rate may be required.

More frequent seam testing and precautions to prevent thawing subgrade may have to be taken. Sharp, frozen subgrade should be avoided to eliminate point pressure damage potential.

Sheet temperatures for seaming should normally be below 105°F (40°C). Depending on material type and thickness, higher temperatures may be allowed. It should also be recognized that wind and cloud cover will determine the actual sheet temperature. For temperatures above this value special attention should be paid to the seaming. The volume of fusion chemical and seaming rate must be adjusted at higher temperatures. More frequent destructive testing may be warranted depending upon field conditions. EPI will discontinue field welding if sheet temperature exceeds 140°F.

If geomembrane deployment is required by the OWNER at ambient temperatures below 60°F, adequate means of storing the liner in an area that maintains the material sheet temperature above 60°F must be provided. This sheet temperature must be maintained up to the time the liner is deployed. EPI does not recommend deploying or field seaming geomembranes when ambient temperature is below 40°F. However, in special



circumstances and with proper preparation, installation can be accomplished at lower temperatures only with the OWNER'S approval of the procedures and any additional costs.

Geomembrane placement will not be done during any precipitation, in the presence of excessive moisture, (e.g., snow, fog, rain, dew, mud) or in the presence of excessive winds, or upon a frozen subgrade, as determined by the installation Foreman.

#### **4.05 UNPACKING THE PANELS**

During the unfolding of the geomembrane, EPI will visually inspect each sheet. Damaged or suspect areas will be marked for testing and/or repair. Geomembrane that is damaged during deployment that cannot be adequately repaired will be replaced at EPI's expense.

#### **4.06 PANEL DEPLOYMENT**

The number of panels to be deployed in any day will be limited to the number of panels which can be seamed that day. The geomembrane will be placed over the prepared surface in such a manner as to assure minimum handling.

The PVC or UltraTech geomembrane will be installed in a relaxed manner and will be free of tension and stress. Stretching of the membrane material shall not be allowed.

All panels may be repositioned after deployment to meet the overlap requirements; however, deployment and repositioning measures shall not involve dragging or elongating the geomembrane panels.

When possible, the seam overlap should be in the predominant wind direction to reduce wind lift.

#### **4.07 PENETRATIONS**

Panels around piping penetrations or other projections through the panel will be cut with rounded corners to prevent tear propagation and ballasted to prevent wind lift until the pipe boot can be installed (see section 4.13).

#### **4.08 FACTORY SEAM QUALITY VERIFICATION**

EPI will visually inspect factory seams after the panel is deployed. Additional testing of factory seams in the field will be done at the OWNER'S expense. All factory seams are tested per Section Two of this document.

#### **4.09 FIELD SEAM PREPARATION**

A six - inch wide overlap must be cleaned of all dust, dirt or foreign debris no more than 30 minutes prior to applying the chemical fusion agent. Only clean, soft rags will be used



for cleaning. If mud has adhered to the sheet surface overlap area, it will be removed with clean water and allowed to dry prior to seaming.

During the cleaning operation, the sheet will be inspected for defective areas which must be removed and/or repaired prior to seaming. The seaming operation requires a solid, smooth subsurface. Subsurface voids, hard nodules, rocks, soft areas or unsuitable conditions will be removed or repaired prior to seaming during subgrade preparation.

Seaming cannot be conducted in the presence of standing water. Wet surfaces must be allowed to dry. A slip sheet or seaming board may be used to lift the geomembrane above damp surfaces. If wind conditions contaminate the seaming area or displace the geomembrane sheets, temporary ballast and additional cleaning procedures will be required.

If weather conditions are not satisfactory, panels will not be put into place. If panels are placed and pulled out, the installation crew will do what is necessary to finish or secure those individual panels that day.

#### **4.10 FIELD SEAMING - CHEMICAL FUSION WELD**

All field seams will be a minimum of 2 inches wide. A sufficient amount of chemical fusion agent will be applied that, upon compressing the seam surfaces together, a thin excess of chemical fusion agent will be forced out.

A high durometer rubber, nylon or steel roller will be used to compress the seam surfaces together until a bond is formed. Roller action will be at a parallel direction to the seam's edge so that excessive amounts of chemical fusion agent will be purged from between the sheets.

Trapped chemicals should be rolled out of the seaming area. Care will be exerted in applying the chemical fusion agent.

A continuous wet layer of chemical fusion agent is necessary to prevent a leak at the tie-in point between the last chemical fusion agent application and the next. If the chemical fusion agent, which is initially shiny when applied, takes on a dull filmy appearance, the interfaces may require a faster closing together or the ambient temperature is too high to continue seaming. EPI will monitor this condition at sheet temperatures over 105°F.

At the completion of seaming, all rags, chemical containers, etc., will be properly removed from the geomembrane.

#### **4.11 FIELD SEAMING – THERMAL WELD**

EPI has pioneered the methodology and equipment modifications to provide for thermal welding PVC, UltraTech and other thermoplastic geomembranes, especially when ambient temperatures fall below 60F. EPI's thermal welds will meet or exceed the minimum PVC Geomembrane Institute's 1104 specification for bonded seam strength and peel adhesion. The thermal welding method does not require preheating of the



geomembrane prior to welding, provided the sheet is warm enough to be deployed without wrinkles.

The principle of a thermal weld is that both surfaces to be joined come into intimate contact with the heat source between the upper and lower layer of the geomembrane sheet surfaces, melting the surfaces, fusion is brought about by compressing the two melted surfaces together, causing an intermingling of the polymers from both sheets. The heat source itself melts the surface of the viscous polymer sheets, followed closely by the nip rollers which squeeze the two geomembranes intimately together.

Temperature controllers on the thermal welding device should be set according to type of geomembrane, thickness, ambient temperature, rate of seaming and location of thermocouple within the device. Ambient factors such as clouds, wind, and sun require temperature and rate of travel settings to vary. Records for destructive test samples will include the temperature and travel rate settings of the thermal welder used to construct the seam.

It is necessary that the operator keep constant visual contact with the temperature controls, as well as the completed seam coming out of the machine. Occasional adjustments of temperature or speed as the result of changing ambient conditions will be necessary to maintain a consistent seam. Constant visual and hands on inspection is also required.

A five foot test strip will be fabricated and test specimens manually tested prior to constructing each seam, or at any time the seaming procedure (e.g. speed, machine temperature) has changed. A minimum of one test strip will be made each morning and afternoon prior to commencement of welding.

On butt welds across ends of panels, it may be necessary to trim any loose edges of the field seams.

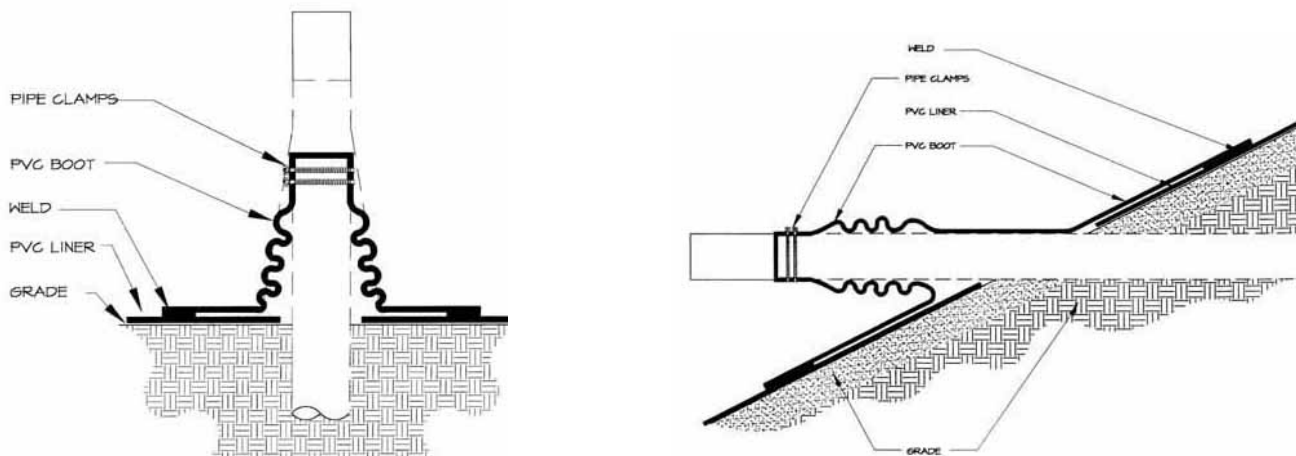
#### **4.12 REPAIRS**

Fish mouths or wrinkles at the seam overlaps will be cut back and overlapped, then patched with an oval or round patch of the same material and thickness as the primary geomembrane.

Patches are also necessary where destructive samples are removed or if material is damaged. Patches will extend 6 inches beyond the area to be repaired, be oval or rectangular with round corners, and will be chemically welded a minimum of 2 inches around the perimeter.

#### **4.13 TAILORING BOOTS AND SHROUDS**

All geomembrane boots and shrouds will normally be of the same material and thickness as the geomembrane specified for the project and will be bonded using fusion chemical, adhesive, thermal weld. All pipe boots will fit snugly without wrinkles or fish mouths. Unacceptable boots will be replaced or repaired. Geomembrane under the pipe boot must remain in contact with subsurface.



#### 4.14 BOOT INSTALLATION

- 1) Prepare the subgrade around the area of the pipe. The sub-grade must be smooth, uniform, and free of any protrusions.
- 2) Clean the surface of the liner around the penetration where the boot will be welded in place. Wipe away any dirt or dust particles. The surfaces of the liner, boot, and the pipe must be completely clean and dry.
- 3) Slide the boot sleeve on the pipe, making sure the boot is aligned and all surfaces are smooth. It may be necessary to trim the excess tapered portion of the boot sleeve.
- 4) Weld the boot apron to the liner using EPI provided adhesive. Apply the adhesive to the liner and the boot apron. Let the adhesive setup for several seconds before pressing the boot apron and the liner together using a roller. Make sure to smooth out any bubbles or wrinkles.
- 5) Seal the boot sleeve to the pipe using two stainless steel hose clamps. The clamps around the pipe will form a watertight seal to the pipe.

#### 4.15 BACKFILLING AND COVERING THE GEOMEMBRANE

The anchor trench will be backfilled and compacted by the contractor as approved by the INSPECTOR. Trench backfill material should be placed in loose lifts and compacted.

The PVC geomembrane must be covered with a minimum of 12 inches of clean soil, free of sticks, stones larger than 1/2 inch diameter, rubbish, or any other material which may



damage the liner. The cover material should be placed over the liner as soon as practical after the liner is installed.

Care should be taken when backfilling the trenches and covering the liner to prevent any damage to the geomembrane or other geosynthetics. At no time will construction equipment come into direct contact with the geomembrane. If damage occurs, it will be repaired by EPI, at the backfilling contractor's expense, prior to the completion and backfilling.

## **5. CONSTRUCTION QUALITY CONTROL**

### **5.01 FIELD SEAM TESTING**

Field Quality Control seam testing involves both non-destructive and destructive testing. The non-destructive testing is primarily centered around determination of "water tightness"; whereas destructive testing is based on ASTM D882 and ASTM D413 test methods.

The OWNER or his designated representative, have the right of access for inspection of any or all phases of the installation and testing, and to perform additional testing at their expense.

Each seam must be checked visually for uniformity of width and surface continuity. Proper fusion chemical application visually changes the surface appearance. Usually the installer will use an air lance or blunt - end pick to check for voids or gaps under the overlapping geomembrane.

When unbonded areas are located, they can sometimes be repaired by inserting more chemical fusion agent into the opening and applying pressure. If that is not satisfactory, a round or oval patch must be placed over them with at least 6 inches of geomembrane extending on all sides.

Any area of the geomembrane sheets where puncture holes are observed must be patched as above, with at least 6 inches of geomembrane extending beyond the affected areas.

Note that with the above items, it is not practical to use a seaming board or slip sheet beneath the geomembrane. However, a piece of the liner material can be used for added support under the liner, if needed, even if the hole must be enlarged to insert the piece before the patch is made. This added piece is left in place. In either situation, additional care should be used to ensure a proper bond.

### **5.02 NON - DESTRUCTIVE SEAM TESTING**

EPI will non-destructively test all field seams over their full length, using an air lance unit. Testing will be performed as the seaming work progresses, not at the completion of all field seaming. This will ensure that the covering process can continue while additional liner is installed.



a) AIR LANCE TEST

The air lance will be capable of supplying 50 PSI through a 3/16 inch diameter nozzle. The air stream is directed at the upper edge of the seam no more that 2 inches from the seam edge.

Any voids in the seam will be marked, repaired, and re - tested with the air lance. The EPI testing technician and the inspector will mark each seam with an indelible marker as accepted immediately after completion of final air lance testing.

b) AIR CHANNEL TEST

For dual track welded seams, the air channel will be sealed at each end and the air channel pressurized with a manometer. Air channel testing will be performed according to ASTM D7177-05 Standard Specification for Air Channel Evaluation of Polyvinyl Chloride (PVC) Dual Track Seamed Geomembranes.

**Air Channel Test Requirements**

Sheet Temperature °C	Sheet Temperature °F	Air Pressure KPa	Air Pressure PSI	Hold Time
4.5	40	414	60	30 Seconds
7	45	386	56	30 Seconds
10	50	358	52	30 Seconds
13	55	324	47	30 Seconds
15.5	60	290	42	30 Seconds
18	65	276	40	30 Seconds
21	70	248	36	30 Seconds
24	75	234	34	30 Seconds
26.5	80	200	29	30 Seconds
29.5	85	186	27	30 Seconds
32	90	172	25	30 Seconds
35	95	165	24	30 Seconds
37.5	100	152	22	30 Seconds
40.5	105	138	20	30 Seconds
43.5	110	131	19	30 Seconds

The project ENGINEER will sign EPI's verification of field seam inspections after non - destructive testing and prior to covering the geomembrane.

c) VACUUM BOX TESTING

Vacuum Box testing is not used on PVC or UltraTech® seams.



### 5.03 DESTRUCTIVE SEAM TESTING

EPI will conduct a minimum of one destructive test per 500 feet of field seam, unless Dual Track Welding & Air Channel Testing is done. Air Channel testing per ASTM D7177 is an acceptable destructive seam testing method. THEREFORE, NO DESTRUCTIVE SAMPLES WILL BE TAKEN FROM PRODUCTION FIELD SEAMS THAT HAVE BEEN AIR CHANNEL TESTED. In order to obtain test results prior to completion of geomembrane installation, samples are cut as the seaming progresses. EPI will mark all samples with their location, panel and seam number. EPI will also record the date, time, name of technicians, ambient temperature and subgrade condition at the time the seam was made. All holes in the geomembrane resulting from obtaining seam samples will be repaired and non - destructively tested.

Any additional destructive testing required by the OWNER or his representative must be requested in writing and will be done at the OWNER's expense.

A copy of the Field Seam Quality Control Record Form is included in Appendix A.

### 5.04 DESTRUCTIVE TEST PROCEDURES

Samples will be at least 12 inches wide and 12 inches long, with the seam centered lengthwise. If any other samples are required for archive or independent laboratory testing the sample shall then increase in 12 inch increments per sample required. The sample, when larger than twelve inches in the lengthwise direction, shall be divided into equal length pieces. One part is to be retained by EPI for testing, any other parts will be delivered to the OWNER or ENGINEER. Additional samples may be added as required for onsite testing with a portable tensiometer.

The sample sent to EPI's lab or any other testing lab will be allowed to acclimate for 40 hours at laboratory temperature (74°F +/- 10°F and 60% +/- 10% RH) prior to testing.

The 12" sample will be cut into ten(10) one-inch(1") wide specimens. Five specimens will be tested for bonded seam strength and five for peel adhesion. To be acceptable, the average of five test specimens must meet the minimum peak load requirements of factory seams as follows:

a) Bonded Seam Strength

One-inch(1") strips cut with the weld centrally located are tested by stressing the weld in a "shear" configuration. That is, the top sheet is stressed in relation to the bottom sheet in a direction away from the weld. A pass result occurs when the specimens meet the minimum peak load requirements stated in the specification (80% of specified sheet strength). A fail occurs when the weld separates or the material breaks at a peak load less than the minimum requirement. The test result to be reported is the average of the peak loads recorded for each of the five specimens.

b) Peel Adhesion

One-inch(1") strips cut with the weld centrally located are tested by stressing the top sheet in relation to the overlapped edge of the lower sheet



in an effort to peel the weld away. A pass result occurs when the specimen meets the minimum peak load requirements stated in the contract. A fail occurs when the weld peels at a peak load less than the specified strength per inch width without film tearing bond. The test result to be reported is the average of the peak loads recorded for each of the five specimens.

**5.05 TEST FAILURE PROCEDURES**

The following procedure will apply whenever a sample fails a destructive test. EPI will either:

- a) Reconstruct the seam between any two passed test locations, or
- b) Trace the seam outward to intermediate points (at least 10 feet from the location of the failed test in each direction) and take a small sample for additional field tests at each location. If these samples pass the field test, a full sample will be cut for verification. The seam is then reconstructed between these two locations. If an intermediate sample fails, the process is repeated to establish the zone in which the seam should be reconstructed. All reconstructed seams must be bounded by two locations from which samples passing other destructive tests have been taken. Over the length of the unacceptable seam (seam between two successful test locations that bracket a test failure), EPI will either cut out the old seam, reposition the panel and re - seam or add a 6 inch *wide* cap strip. In cases exceeding 150 feet of reconstructed seam, a sample taken from the zone in which the seam has been reconstructed must pass destructive testing.

**5.06 OWNER APPROVALS**

The OWNER or his representative will be notified and requested to witness all non - destructive testing of field seams. EPI will not be prevented from continuing non - destructive testing during normal working hours if the OWNER or his representative declines to witness the testing.

After each field seam has passed the tests described herein, the project ENGINEER is requested to sign an EPI Seam Inspection report on those seams prior to the covering of the geomembrane. The project ENGINEER will be requested to sign EPI's verification of field seam inspections and air lance testing prior to covering the geomembrane.

At the completion of the installation the OWNER or his representative shall confirm in writing that all of EPI's site requirements have been completed as specified.

**5.07 DOCUMENTATION**

EPI's field installation foreman will maintain a log of each day's work. Included in this log will be:

Date	Ambient temperature
Panels deployed	Weather conditions
Inspections	Field seams constructed
Seaming technicians	Any other site specific conditions



## **5.08 INSTALLATION ACCEPTANCE**

EPI will retain all responsibility for the geomembrane installation until acceptance or covering of the geomembrane by the OWNER or his representative.

The geomembrane liner installation will be accepted by the OWNER or his representative when all of the following conditions have been met:

- a) Installation is completed.
- b) Verification of the adequacy of all field seams and repairs, including associated testing, as required by the specification, is complete.
- c) Sign off, of completed installation, is provided to EPI by the OWNER or his representative.

## **6. SAFETY POLICY**

Environmental Protection, Inc. is committed to the protection of the health and safety of its workers and will take all reasonable measures to achieve this goal. Therefore, the Company is committed to the prevention of personal injury, occupational disease and the protection from accidental loss of all of its resources, including employees, the environment and its physical assets.

In order to fulfill this commitment to protect both people and property, the Company will provide and maintain a safe and healthy work environment according to acceptable industry standards and in compliance with legislative requirements. The Company will strive to eliminate any foreseeable hazards which may result in fires, explosions, security losses, property damage, accidents, personal injuries and/or illnesses.

Environmental Protection, Inc. has the ultimate responsibility to ensure that every reasonable precaution is taken to protect its employees health and safety by working in compliance with the law and with safe work practices and procedures established by the Company.

Managers and supervisors will be held accountable for the health and safety of the employees under their supervision. It is each supervisor's responsibility to comply with, and promote among their workers, the corporate philosophy of health and safety protection and loss control.

In addition to complying with established standards, striving for loss prevention is a company priority objective. Control of losses can only be achieved through the combined efforts of all the employees of Environmental Protection, Inc.. Identification of areas where potential losses may occur is the responsibility of all managers, supervisors and employees. By working together, hazards which have the potential to result in fire, explosions, security losses, property damage or personal injuries / illnesses can be minimized and incidents can be avoided.



## 6.01 SAFETY AND HEALTH PROGRAM

### EPI's comprehensive safety and health program includes:

1. Monthly safety meetings for all employees covering:
  - a) Personal Protective Equipment
  - b) Hazardous materials "Right to Know"
  - c) Emergency action plan
  - d) Lockout Tagout Procedures
  - e) Blood borne Pathogens
  - f) Housekeeping
  - g) Communicable Disease
  - h) Accident Reporting
  - i) Fire extinguishers/Fire Prevention, Safety
  - j) Lifting Back Safety
  - k) Vehicle & HI - LO Safety
  - l) OSHA/MIOSHA Inspections
  - m) Drugs & Alcohol
  - n) Safety Attitudes
  - o) Fire Drills
  - p) Natural Disasters
  - q) Environmental Emergencies
  - r) Slips and Falls
  
2. Specialized training as required, including
  - a) CPR \ Cardiopulmonary resuscitation
  - b) First aid procedures
  - c) Hazardous Materials Handling Training
  
3. Documented and implemented policies covering:
  - a) Lockout Tagout
  - b) Safety Glass Requirements
  - c) Hazard Communication Plan "Right to Know"
  - d) Emergency Action Plan
  - e) General Housekeeping
  - f) Accident Reporting
  - g) Right to Know Center "MSDS"
  - h) Standard Operating Procedures
  - i) Hazardous Materials List
  
4. Designated safety program leadership and coordination including:
  - a) Company Safety Director
  - b) TQM / Safety team
  - c) New Employee Orientation
  - d) Monthly Safety Inspections and follow up
  - e) Safety Recognition Awards
  - f) Voluntary Government agency inspections and Environmental testing
  - g) Preparation and Publication of appropriate safety reports

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## REFERENCES

1. Technical Guidance Document, "Inspection Techniques for the Fabrication of Geomembrane Field Seams", EPA/530/SW-91/051, U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Washington, D.C., May 1991.
2. Plastics World, "PVC Geomembranes", Wolschon Test, 275 Washington St., Newton, MA, October 1993.
3. Technical Recourse Document, "Lining of Waste Containment and Other Impoundment Facilities", EPA/600/2-88/052, U.S. Environmental Protection Agency, Risk Reduction Engineering Laboratory, Cincinnati, OH, September 1988.
4. Technical Guidance Document, "Construction Quality Management for Remedial Action and Remedial Design Waste Containment Systems." EPA / 540 / R - 92 / 073, U.S. Protection Agency, Office of Solid Waste and Emergency Response, Washington, D.C., October 1992.
5. PVC Geomembrane Institute, Construction Quality Control Document - Dated April 1995.
6. PVC Geomembrane Institute material specification 1104 dated 1-1-2004
7. PVC Geomembrane Institute Technical Bulletin : "New Standards For PVC Geomembranes", August 1997.
8. PVC Geomembrane Institute Technical Bulletin : "Wedge Welding PVC Geomembranes", May 1998
9. PVC Geomembrane Institute Technical Bulletin : "Specification For Thermal Welding PVC Geomembranes", December 1998.
10. ASTM D7177 : Standard Specification for Air Channel Evaluation of Polyvinyl Chloride (PVC) Dual Track Seamed Geomembranes



## APPENDIX A

1.	PVC Physical Properties Specification .....	A-1
2.	UltraTech Physical Properties Specification .....	A-2
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